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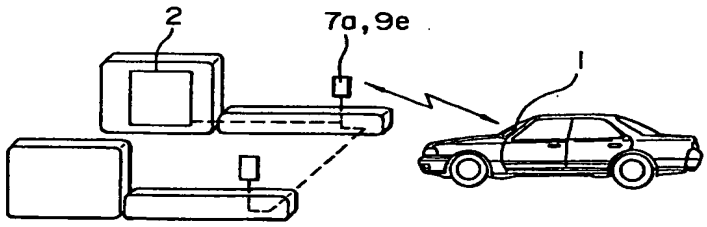
(54) Radio IC card system

(57) A radio IC card system includes an IC card (1) and a toll collector (2). When an automobile with the IC card passes by a tollgate, the toll collector (2) installed in the tollgate transmits a signal which is spread modulated by using a pseudorandom noise (PN) code from an antenna. The signal is received by the antenna (11) of the IC card and is inputted to a surface acoustic wave (SAW) correlator (12). The SAW correlator (12) extracts a PN code included in the received signal, and outputs a peak signal. An accumulation circuit (16) accumulates the peak signal. A threshold discharger (18) is activated to switch on a relay switch (R2) when the output voltage of the accumulation circuit (16) exceeds a constant value. Thereby, the voltage of a battery (20) is supplied to a data communication unit (21). Then, the identification code of the IC card and a record of tollgates by which the automobile has passed are transmitted to the toll collector (2).

FIG. 1



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Descripti n

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to radio integrated circuit (IC) card systems in which power consumption is reduced.

2. Description of the Related Art

Nowadays, research on various types of systems utilizing IC cards is in progress.

IC cards are expected to be applied to various fields because they can be provided with a mass storage unit and a central processing unit (CPU) for processing data stored in the storage unit, different from magnetic cards.

At present, IC card systems are classified into a contact IC card system and a radio IC card system (non-contact IC card system).

Fig. 11A shows a block diagram of a contact IC card system.

According to this contact IC card system, transmission or reception of data is performed between an IC card system 100 and a reader/writer unit 101 via connectors 102 and 103.

Since the IC card system 100 and the reader/writer unit 101 are connected by the connectors 102 and 103, a CPU 104 in the IC card 100 can be supplied with power through the connectors 102 and 103.

Fig. 11B shows a block diagram of a conventional radio IC card system.

According to this radio IC card system, transmission or reception of data is performed by radio between an IC card 200 and a reader/writer unit 201 via a transmitter/receiver unit 202. Since this system is radio-operated, the IC card 200 cannot be supplied with power from the reader/writer unit 201. Consequently, the IC card 200 needs a built-in battery 204 to supply power to the transmitter/receiver unit 202 and the CPU 205.

Although the radio IC card system has such a complicated structure than the contact IC card system, transmission or reception of data can be performed over a distance between the IC card 200 and the reader/writer 201. Thus, the radio IC card system can be applied to a wide range of fields such as transport, distribution, and factory automation. For example, by using radio IC cards disposed in automobiles and reader/writer units disposed in tollgates, the identification code of each automobile and the tollgate by which the automobile has passed can be recorded without a halt of the automobile at the tollgate because transmission or reception of data can be performed between the IC card and the reader/writer unit. Afterward, the toll is online collected from the bank account specified by the identification code.

Concerning the above-described radio IC card system, what should be solved is power consumption while the transmitter/receiver unit is in standby mode.

In other words, to activate the transmitter/receiver unit 202 in the IC card 200 by radio, the transmitter/receiver unit 202 needs to always stand by (to be in a condition capable of receiving radio waves). For this purpose, the active state of the transmitter/receiver unit 202 must always be maintained.

However, maintaining the active state of the transmitter/receiver unit 202 as always active increases power consumption of the unit 202, and as shown in Fig. 11B, activation of the transmitter/receiver unit 202 by the battery 204 extremely shortens the life of the battery 204 due to power consumption of the transmitter/receiver unit 202.

Otherwise, the above problem is also solved by providing a switch to the battery 204 so that the switch is activated only when the IC card is used.

However, the IC card is thin by nature, and is weak against externally applied force, thus, it is not preferable to use a switch-like mechanical member mounted to the IC card, judging from durability.

In addition, compared with the contact IC card system, the radio IC card system has an advantage in which the iC card functions without connection to the connector of the reader/writer unit, in other words, it is automatically operated not by being touched by the user but only by being possessed by the user. This advantage is lost in the IC card if the power switch must be turned on for each use.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide an IC card to be automatically activated to transmit or receive data when receiving a radio signal, in which power consumption in standby mode can be reduced to zero or the vicinity thereof, and a radio IC card system utilizing such an IC card.

According to a first aspect of the present invention, the foregoing object is achieved through the provision of an IC card including radio switching means being activated when receiving data having a predetermined particular pattern, and a data communication unit transmitting data to and receiving data from a radio data transmitter/receiver device having transmitted the data having the particular pattern when being supplied with power in accordance with the activation of the radio switching means, while processing the data, and breaking the power supply after terminating transmission or reception and processing of the data.

Preferably, the radio switching means includes a receiving antenna, a surface acoustic wave device to which a signal received by the receiving antenna is applied for extracting a particular pattern included in the signal, an accumulation circuit for accumulating output power from the surface acoustic wave device, and a switching circuit being activated when the output power from the accumulating circuit exceeds a constant value.

The surface acoustic wave device may comprise a surface acoustic wave (SAW) matched filter.

The SAW matched filter may include an Al_2O_3 substrate, an AlN film formed on the Al_2O_3 substrate, and an Al tapping pattern formed on the AlN film.

According to a second aspect of the present invention, the foregoing object is achieved through the provision of a radio data transmitter/receiver device including switch-activation means for transmitting data having a predetermined particular pattern, and transmitter/receiver means for transmitting the data having the particular pattern to and for receiving the data having the predetermined pattern from a data communication unit activated by the data having the particular pattern.

Preferably, the switch-activation means includes noise code generating means for generating a pseudorandom noise code, modulation means for modulating a carrier by using the noise code, and an antenna for radiating a signal modulated by the modulation means in the air.

According to a third aspect of the present invention, the foregoing object of the present invention is achieved through the provision of a radio IC card system comprising: an IC card including radio switching means being activated when receiving data having a predetermined particular pattern, and a data communication unit transmitting data to and receiving data from a radio data transmitter/receiver device having transmitted the data having the particular pattern when being supplied with power in accordance with the activation of the radio switching means, while processing the data, and breaking the power supply after terminating transmission or reception and processing of the data; and a radio data transmitter/receiver device including switch-activation means for transmitting data having a predetermined particular pattern, and transmitter/receiver means for transmitting the data having the particular pattern to and for receiving the data having the predetermined pattern from a data communication unit activated by the data having the particular pattern.

The above-described present invention provides a radio IC card system in which high reliability is attained and power consumption while the system is standing by can reduced to approximately zero.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic view illustrating a radio IC card according to an embodiment of the present invention.

Fig. 2 is a block diagram showing the radio IC card according to the embodiment.

Fig. 3 is a block diagram showing a toll collector according to the embodiment.

Figs. 4A to 4C are waveform charts showing signals in portions of a switch-activation circuit shown in Fig. 3.

Fig. 5 is a perspective view illustrating an example of an SAW correlator shown in Fig. 2.

Fig. 6 is a circuit diagram showing an accumulation circuit shown in Fig. 2.

Figs. 7A and 7B are waveform charts showing the operation of the circuit shown in Fig. 6.

Fig. 8 is a circuit diagram showing a threshold discharger and a relay switch shown in Fig. 2.

Fig. 9 is a block diagram showing a data communication unit shown in Fig. 2.

Fig. 10 is a circuit diagram showing a modification of the circuit shown in Fig. 8.

Figs. 11A and 11B are block diagrams showing a contact IC card system and a conventional radio IC card system, respectively.

DESCRIPTION OF THE PREFERRED EMBODIMENT

By referring to the attached drawings, an embodiment of the present invention will described below.

Fig. 1 shows a schematic view illustrating a radio IC card system according to one embodiment of the present invention. An IC card 1 is disposed inside the front windowshield of an automobile. Whenever the automobile runs on a toll road, the code of tollgate at which the automobile goes into the toll road and the code of a tollgate at which the automobile gets out of the toll road are stored as a record in the IC card 1.

A toll collector 2 is installed at the tollgate, which activates the IC card 1 over a distance to transmit data to or to receive data from the IC card 1.

The structures and operations of the IC card 1 and the toll collector 2 are as follows:

Fig. 2 shows a block diagram of the IC card 1. Fig. 3 shows a block diagram of the toll collector 2.

As shown in Fig. 3, the toll collector 2 includes a central processing unit (CPU) 3, a read-only memory (ROM) 4 for storing programs used in the CPU 3, a random access memory (RAM) 5 for temporary storage of data, an external interface 6 for connecting the toll collector 2 to various types of terminals (not shown), a transmitter/receiver device 7 for transmitting data to the IC card 1 (shown in Fig. 2) and for receiving data from the IC card 1, and an activation circuit 8 for activating a switch-activation circuit 9 by turning on its power supply switch in accordance with an activation instruction from the CPU 3.

The switch-activation circuit 9 activates the IC card 1 by spread spectrum communication.

The switch-activation circuit 9 includes a PN code generator 9a. A PN code is a cyclic, pseudorandom noise code. Known PN codes are â Maxim in length sequence, a Barker sequence, a Gold sequence, and so forth. The PN code generator 9a repeatedly generates and outputs a PN code shown in Fig. 4A to a modulation circuit 9b during a predetermined period. The PN code shown in Fig. 4A is a 11-chip Barker code, and one cycle of the code is expressed as follows:

11100010010

An oscillation circuit 9c shown in Fig. 3 generates a carrier. The waveform of the carrier is shown in Fig. 4B. The modulation circuit 9b outputs a spread modulated carrier, utilizing the PN code. The output waveform of the modulation circuit 9b is shown in Fig. 4C. The output of the modulation circuit 9b is radiated from an antenna

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9e through a band-pass filter 9d.

The IC card 1 shown in Fig. 2 includes an antenna 11 and a surface acoustic wave (SAW) correlator (SAW matched filter) 12. As shown in Fig. 5 (perspective view), the SAW correlator 12 includes a substrate 12 comprised of Al_2O_3 (sapphire), and an AlN (aluminum nitride) film 12b formed on the Al_2O_3 substrate by an MO-CVD method. An aluminum (Al) input pattern 12c and an Al tapping pattern 12d are formed on the AlN film 12b by an opto-lithography technique. The Al tapping pattern 12d corresponds to the above-mentioned Barker code (11100010010).

When a spread signal shown in Fig. 4C is received by the antenna 11, and is applied to the input pattern 12c of the SAW correlator 12, the applied signal becomes a surface acoustic wave, which is conducted by the surface of the SAW correlator 12 through the tapping pattern 12d. When the phase of the conducted wave motion coincides with the tapping pattern 12d, the amplitude of each wave is integrated, and a correlated peak eleven times the amplitude appears at output ends 12o of the tapping pattern 12d. In other words, as shown in Fig. 2, correlated peaks 14 appear with respect to eleven cycles of the carrier at the output ends of the SAW correlator 12. When the phase of the wave motion does not coincide with the tapping pattern 12d, voltage across the output ends 12o is not more than 1/11 of the correlated peak. The output of the SAW correlator 12 is inputted to an accumulation circuit 16.

The AlN-on-Al_2O_3 structure shown in Fig. 5 has a propagation velocity of approximately 6000 m/second, which is 1.5 to 2 times higher than that of other piezoelectric bodies. This enables a large size to be processed. In addition, the structure has a relatively large electromechanical coupling coefficient of approximately 1%. This causes a propagation period temperature coefficient of zero, so the structure is suitable for a gigahertz-band surface acoustic wave material.

As shown in Fig. 6, the accumulation circuit 16 includes a high frequency coil H comprised of a primary coil L1 and a secondary coil L2, a tank circuit T comprised of the secondary coil L2 and a capacitor C1 which are connected in parallel, a diode D for rectifying th output of the tank circuit T, a capacitor C2 for accumulating the output of the diode D, and a resistor R connected in parallel to the capacitor C2.

The resonance frequency of the tank circuit T coincides with the frequency (2 MHz) of the correlated peak waveform outputted from the SAW correlator 12. As a result, the tank circuit T accepts only components of the correlated peaks, and sequentially accumulates the components. In Fig. 7A, the voltage between both ends of the capacitor C1 is shown. The output voltage of the tank circuit T charges the capacitor C2 via the diode D. As a result, as shown in Fig. 7B, the voltage between both ends of the capacitor C2 successively increases. The voltage of the capacitor C2 is applied to a threshold discharger 18.

A configuration of the threshold discharger 18 and the relay switch R2 is shown in Fig. 8. The threshold discharger 18 includes a Zener diode Dz and a relay switch R1 connected in series to the Zener diode Dz. The relay switch R1 has small power consumption (for example, 50 mW). When the output voltage of the accumulation circuit 16 exceeds the Zener voltage of the Zener diode Dz, the Zener diode Dz is switched on to activate the relay switch R1, and a contact r1 is closed. Thereby, the voltage of the battery 20 is supplied to the relay switch R2 to be activated. Then, contacts r2-1 and r2-2 are closed. When the contact r2-1 is closed, the relay switch R2 is self-held. When the contact r2-2 is closed, the voltage of the battery 20 is supplied to a data transmitting unit 21 to operate.

Fig. 9 shows a block diagram of a data communication unit 21. The data communication unit 21 includes a CPU 23, a ROM 24 for storing the identification code and programs of the IC card, a RAM 25, a transmitter/receiver device 26, an interface circuit 26, and a relay switch R3 which has a normally closed contact r3 inserted in the circuit of the battery 20. A data storage 28, comprising a non-volatile memory (E^2PROM, flash memory, and so forth), stores a record of tollgates by which the automobile has passed. Storage contents of the data storage 28 can be read or written as digital data from an output terminal T.

In the above arrangement, when the contact r2-2 shown in Fig. 8 is closed, the output voltage of the battery 20 is supplied as power supply voltage to the data communication unit 21, so portions of the unit 21 are activated. Then, radio communication is performed between the IC card 1 and the toll collector 2.

In other words, when the automobile with the IC card according to the present invention enters the toll road, with the power supplied to the data communication unit 21 in the above-mentioned operation, the transmitter/receiver device 26 receives a tollgate code which is transmitted by the toll collector 2. The CPU 23 reads the received tollgate code, and writes it into the data storage 28 via the interface 27. With this operation, the tollgate code which represents the tollgate at which the automobile entered the toll road is stored as a record into the data storage 28.

In addition, when the automobile with the IC card 1 according to the present invention gets out of the toll road, with the power supplied to the data communication unit 21, the CPU 23 reads the identification code of the IC card 1 from the ROM 24, and sends the read identification code to the transmitter/receiver device 26. Also, the CPU 23 reads the record stored by the data storage 28 (namely, the tollgate code representing the start point at which the automobile entered the toll road) from the data storage 28 via the interface 27, and sends the read tollgate code to the transmitter/receiver device 26.

The transmitter/receiver device 26 modulates a carrier with the identification code and the tollgate code to transmit the modulated carrier from the antenna 26a in the The transmitted signal is received by the trans-

mitter/receiver device 7 shown in Fig. 3 to be demodulated to the original codes.

Based on the received tollgate code (the toll gate code representing the start point at which the automobile entered the toll road), the CPU 3 in the toll collector 2 calculates the toll. The CPU 3 transmits the received identification code (the identification code of the IC card 1) and the calculated toll online to various types of terminals (not shown) via the external interface 6. The terminals perform toll adjustment process based on the received identification code and the toll.

The CPU 23 shown in Fig. 9 activates the relay switch R3 via the interface 27 when the transmitter/receiver device 26 has terminated data transmission and reception. The activation of the relay switch R3 closes the contact r3 (as shown in Fig. 8), and switches ff the coil power supply of the relay switch R2. Then, the contact r2-2 is open to switch off the power supply of the data communication unit 21.

Details of one embodiment of the present invention have been described. According to this embodiment, the toll of the toll road can be paid from the inside of the automobile without the IC card 1 mounted to the toll collector 2. In addition, according to this embodiment, until the phase of the SAW based on the signal received by the antenna 11 (shown in Fig. 2) completely coincides with the tapping pattern of the SAW correlator 12, the data communication unit 21 is not activated. Thus, the data communication unit 21 hardly malfunctions, so high reliability is advantageously obtained. Moreover, until the relay switch R1 is activated, the circuit of the battery 20 is mechanically, completely isolated by the contacts r1, r2-1 and r2-2. Thus, leakage current is theoretically zero, which reduces the power consumption of the battery 20 while the IC card is in standby mode.

The present invention is not limited to this embodiment but includes modifications within the spirit and scope thereof.

For example, to improve sensitivity, the circuit shown in Fig. 10 may be used for the circuit shown in Fig. 8. The circuit in Fig. 10 includes a photocoupler PC comprised of a light-emitting diode Dp and a MOS phototransistor Tm, instead of the Zener diode Dz and the relay switch R1 both shown in Fig. 8. According to the circuit in Fig. 10, when an output voltage from the accumulation circuit 16 reaches the forward voltage of the light-emitting coupler Dp or higher, the light-emitting coupler Dp emits light, which activates the phototransistor Tm. Then, the relay switch R4 is activated to close contacts r4-1 and r4-2. Closing the contact r4-1 causes the self-holding of the relay switch R4, while closing the contact r4-2 causes the voltage of the battery 20 to be supplied to the data communication unit 21.

According to the circuit in Fig. 10, compared with the circuit in Fig. 8, a smaller output voltage from the accumulation circuit 16 activates the relay switch R4. While the circuit in Fig. 10 is in standby mode, leakage current flows through the relay switch R4 and the phototransistor Tm. However, a leakage current from the phototransistor is 100 pA or less, thus, the circuit in Fig. 10 can substantially reduce power consumption in standby mode to approximately zero.

Claims

1. An IC card including:

   radio switching means being activated when receiving data having a predetermined particular pattern;
   and a data communication unit transmitting data to and receiving data from a radio data transmitter/receiver device having transmitted the data having the particular pattern when being supplied with power in accordance with the activation of said radio switching means, while processing said data, and breaking the power supply after terminating transmission or reception and processing of the data.

2. An IC card according to Claim 1, wherein said radio switching means includes:

   a receiving antenna;
   a surface acoustic wave device to which a signal received by said receiving antenna is applied for extracting a particular pattern included in said signal;
   an accumulation circuit for accumulating output power from said surface acoustic wave device;
   and a switching circuit being activated when said output power from said accumulating circuit exceeds a constant value.

3. An IC card according to Claim 2, wherein said surface acoustic wave device comprises a surface acoustic wave (SAW) matched filter.

4. An IC card according to Claim 3, wherein said SAW matched filter comprises an Al_2O_3 substrate, an AlN film formed on said Al_2O_3 substrate, and an Al tapping pattern formed on said AlN film.

5. A radio data transmitter/receiver device including:

   switch-activation means for transmitting data having a predetermined particular pattern;
   and transmitter/receiver means for transmitting said data having the particular pattern to and for receiving said data having the predetermined pattern from a data communication unit activated by said data having the particular pattern.

6. A radio data transmitter/receiver device according to Claim 5, wherein said switch-activation means includes:

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noise code generating means for generating a pseudorandom noise code;
modulation means for modulating a carrier by using said noise code;
and an antenna for radiating a signal modulated by said modulation means in the air.

7. A radio IC card system comprising:

an IC card including radio switching means being activated when receiving data having a predetermined particular pattern, and a data communication unit transmitting data to and receiving data from a radio data transmitter/receiver device having transmitted the data having the particular pattern when being supplied with power in accordance with the activation of said radio switching means, while processing said data, and breaking the power supply after terminating transmission or reception and processing of the data;
and a radio data transmitter/receiver device including switch-activation means for transmitting data having a predetermined particular pattern, and transmitter/receiver means for transmitting said data having the particular pattern to and for receiving said data having the predetermined pattern from a data communication unit activated by said data having the particular pattern.

8. A radio IC card system according to Claim 7, wherein said radio switching means includes a receiving antenna, a surface acoustic wave device to which a signal received by said receiving antenna is applied for extracting a particular pattern included in said signal, an accumulation circuit for accumulating output power from said surface acoustic wave device, and a switching circuit being activated when said output power from said accumulating circuit exceeds a constant value.

9. A radio IC card system according to Claim 7 or 8, wherein said switch-activation means includes noise code generating means for generating a pseudorandom noise code, modulation means for modulating a carrier by using said noise code, and an antenna for radiating a signal modulated by said modulation means in the air.

10. A radio IC card system according to Claim 8 or 9, wherein said surface acoustic wave device comprises a surface acoustic wave (SAW) matched filter.

11. A radio IC card system according to Claim 10, wherein said SAW matched filter comprises an Al_2O_3 substrate, an AlN film formed on said Al_2O_3 substrate, and an Al tapping pattern formed on said AlN film.

FIG. 1

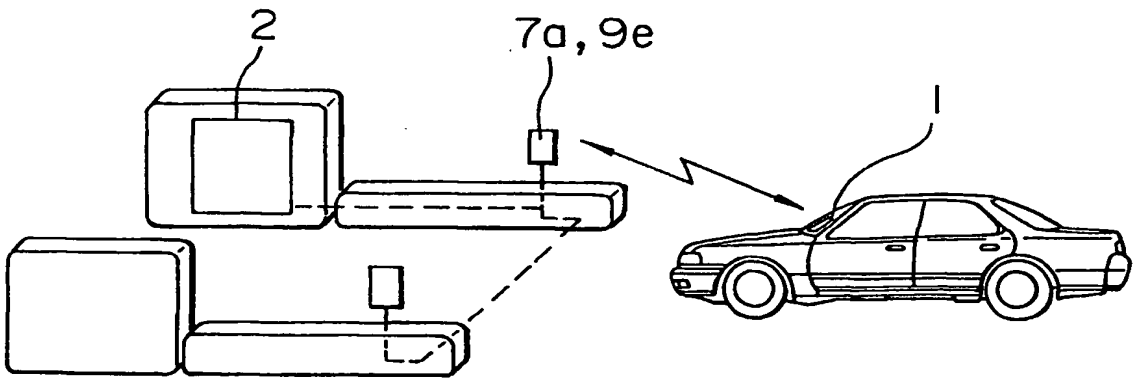

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FIG. 2

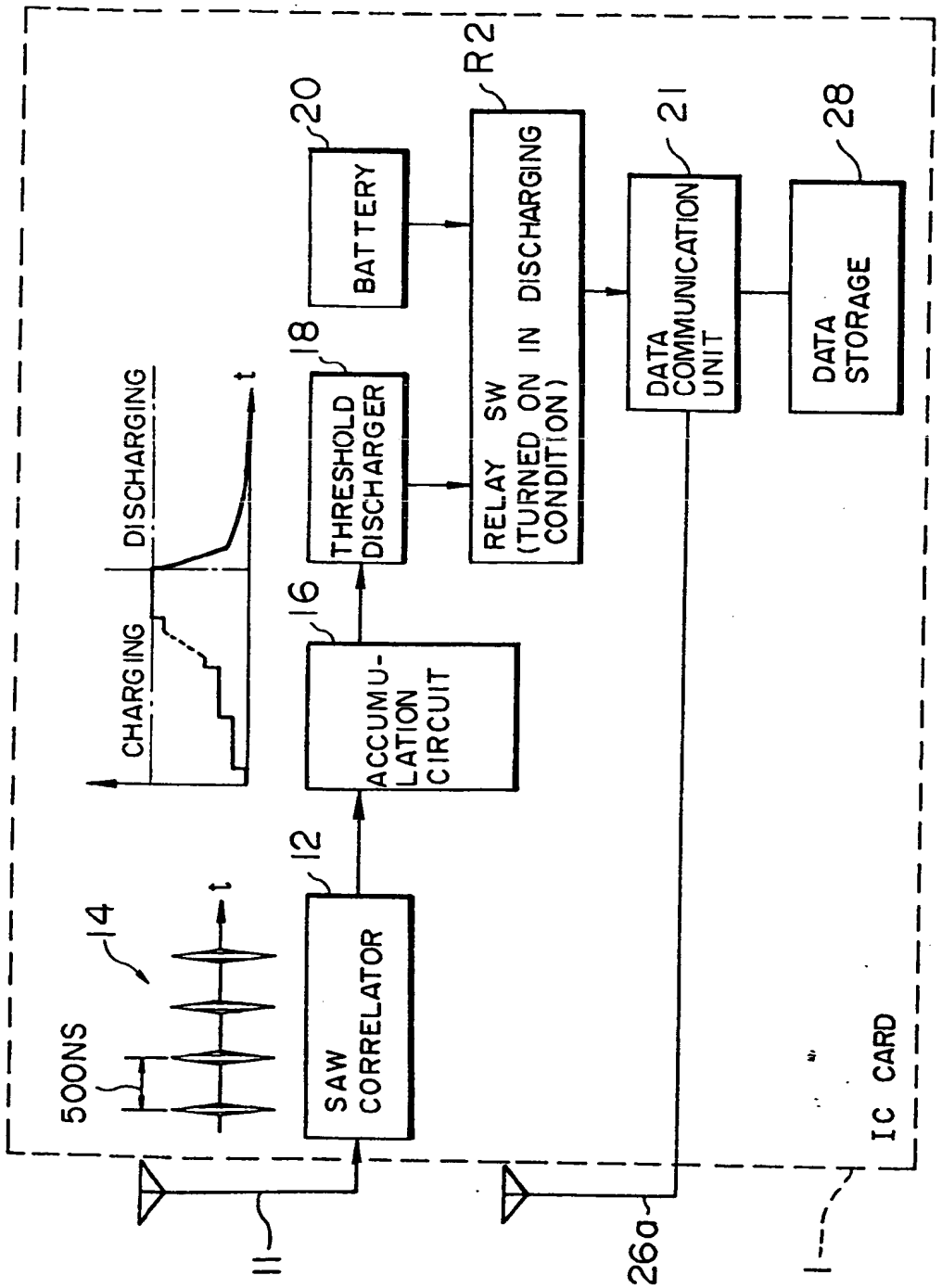
IC CARD
1
11
26a
SAW CORRELATOR
12
500NS
14
t
ACCUMU-LATION CIRCUIT
16
THRESHOLD DISCHARGER
18
BATTERY
20
RELAY SW (TURNED ON IN DISCHARGING CONDITION)
R2
DATA COMMUNICATION UNIT
21
DATA STORAGE
28
DISCHARGING
CHARGING
t

FIG. 3

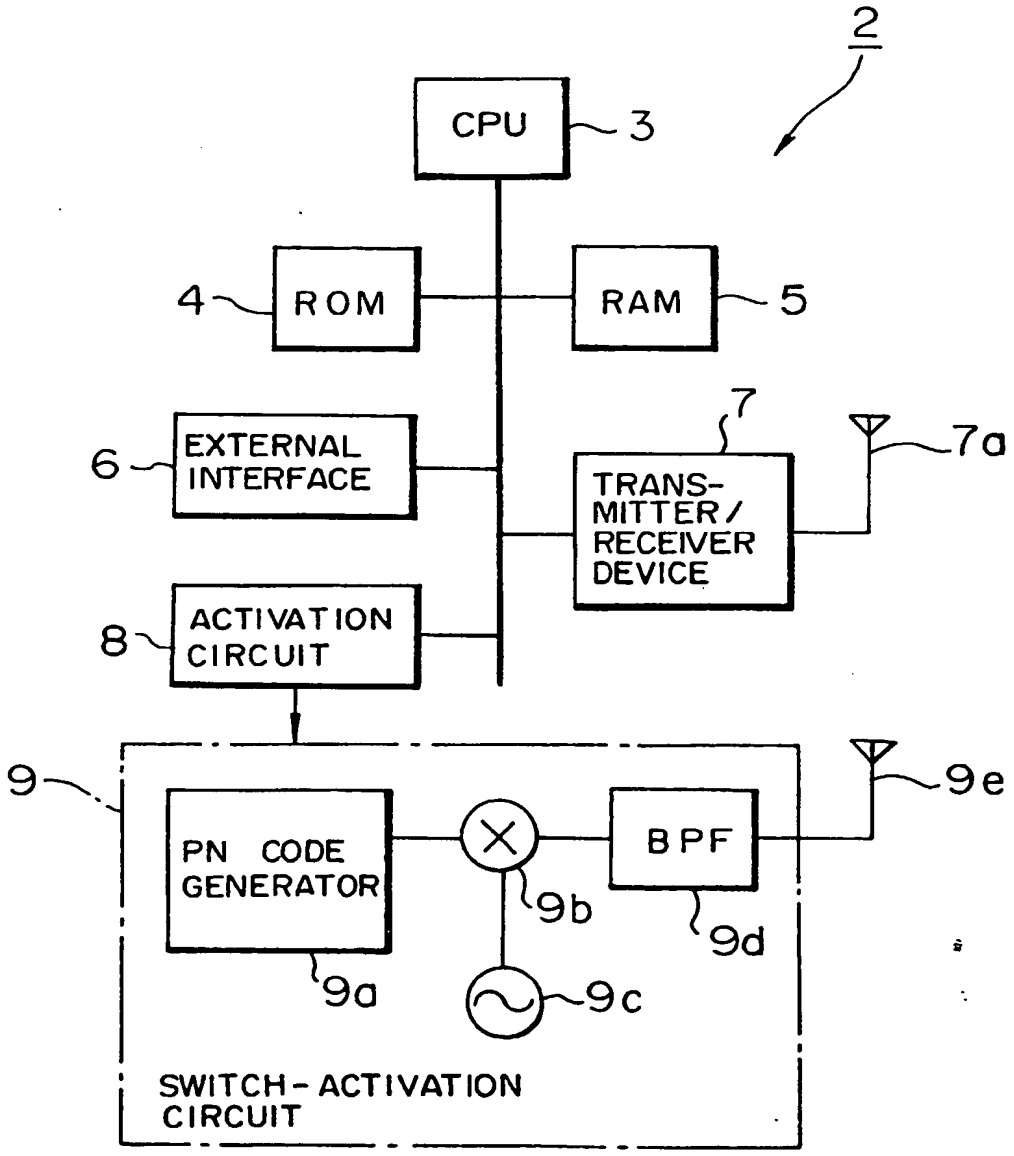

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FIG. 4A PN CODE

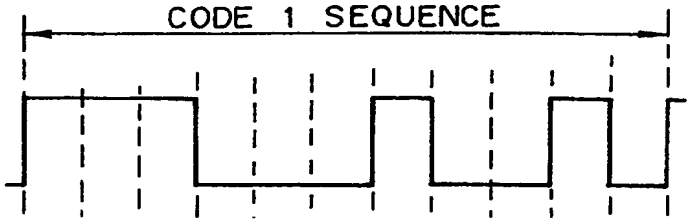

FIG. 4B CARRIER

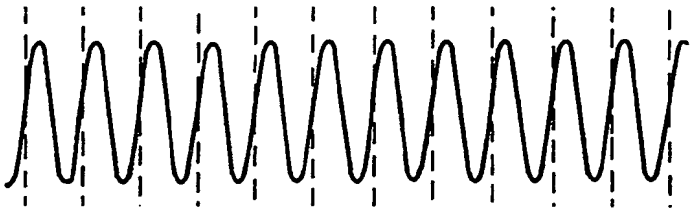

FIG. 4C SPREAD SIGNAL

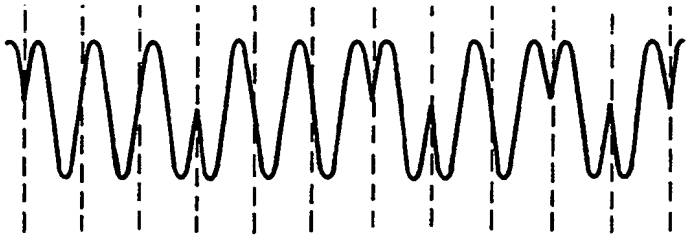

FIG. 5

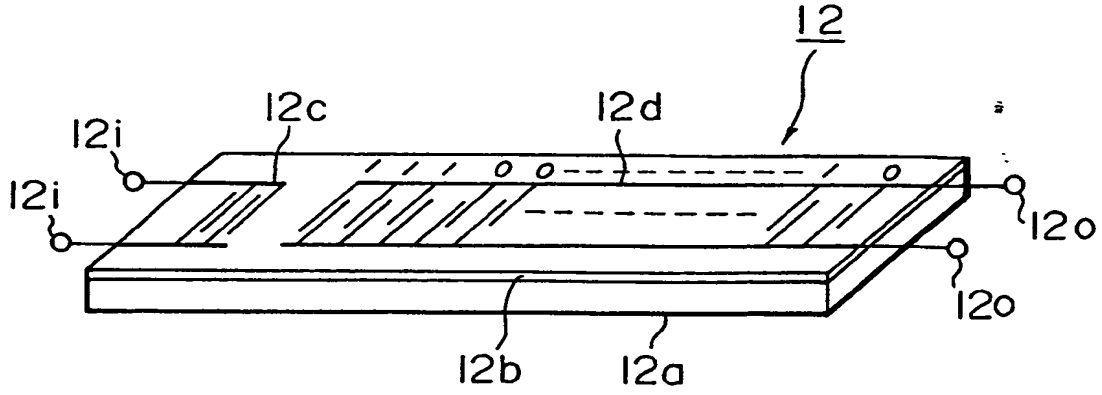

FIG. 6

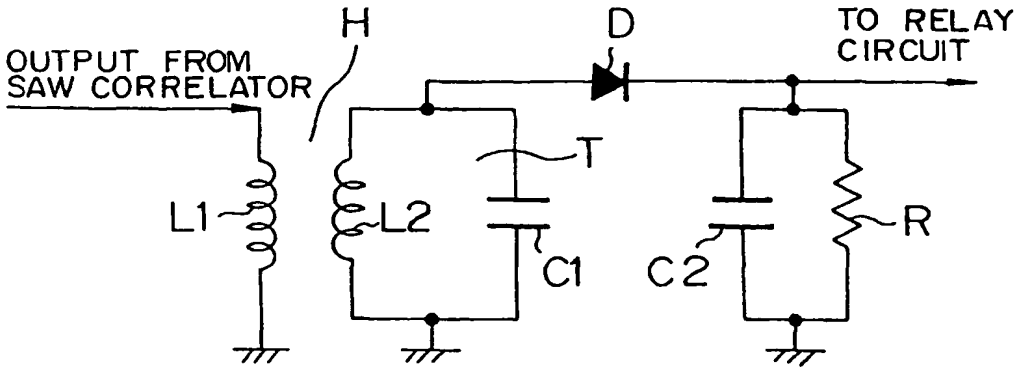

FIG. 7A

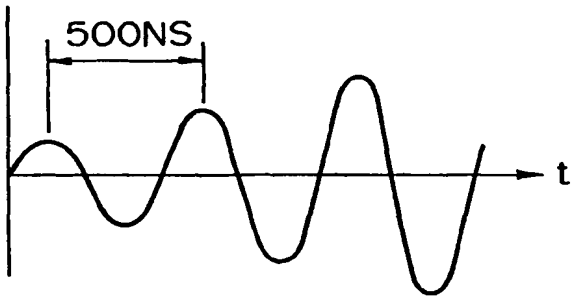

FIG. 7B

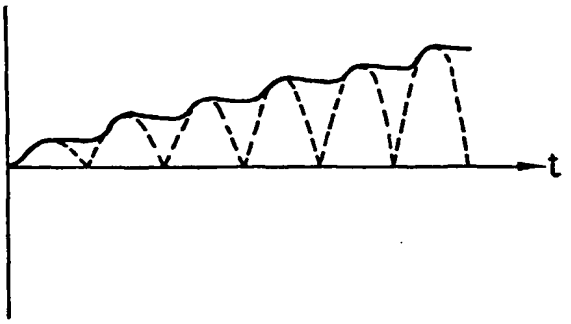

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FIG. 8

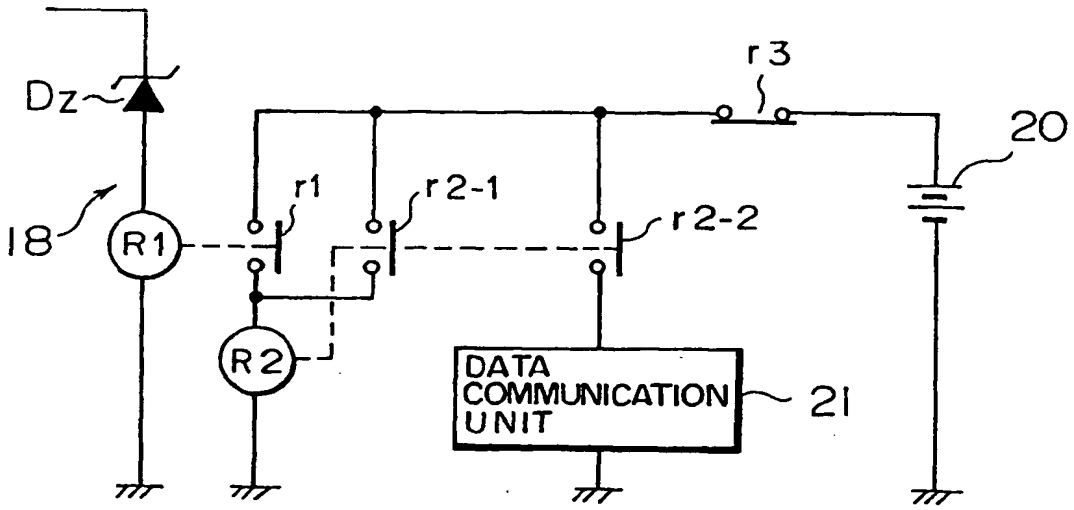

FIG. 9

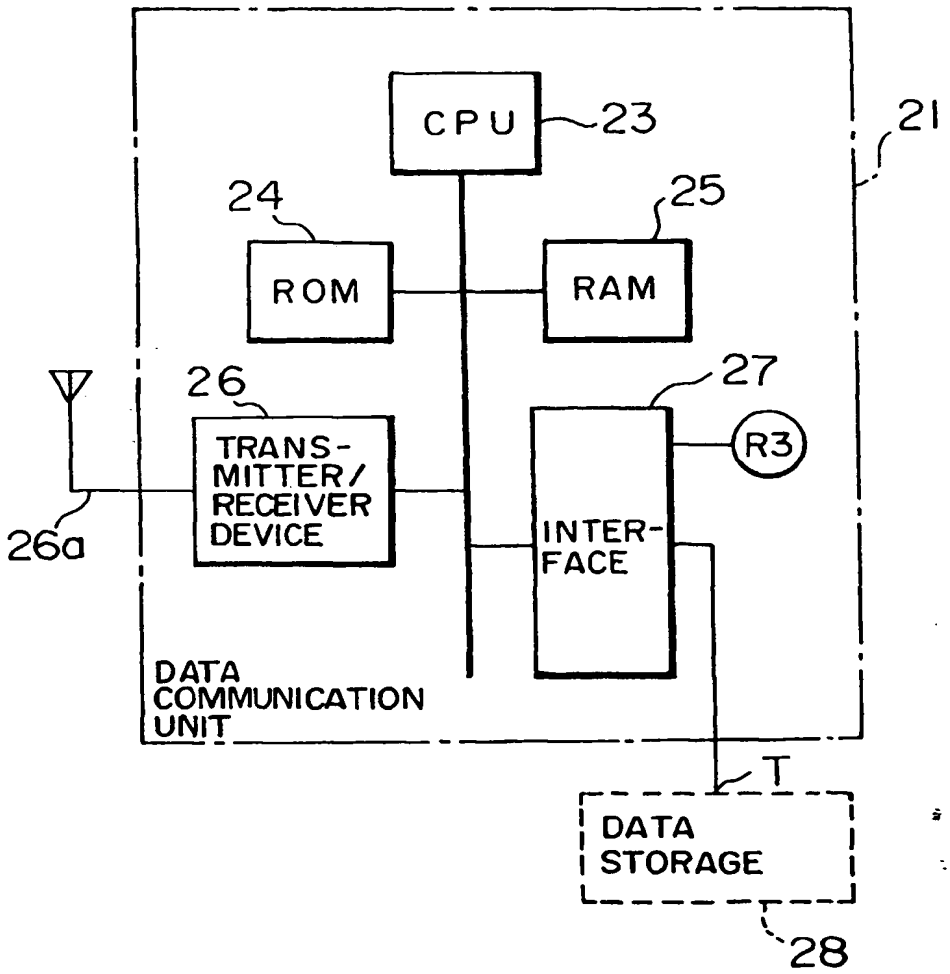

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FIG. 10

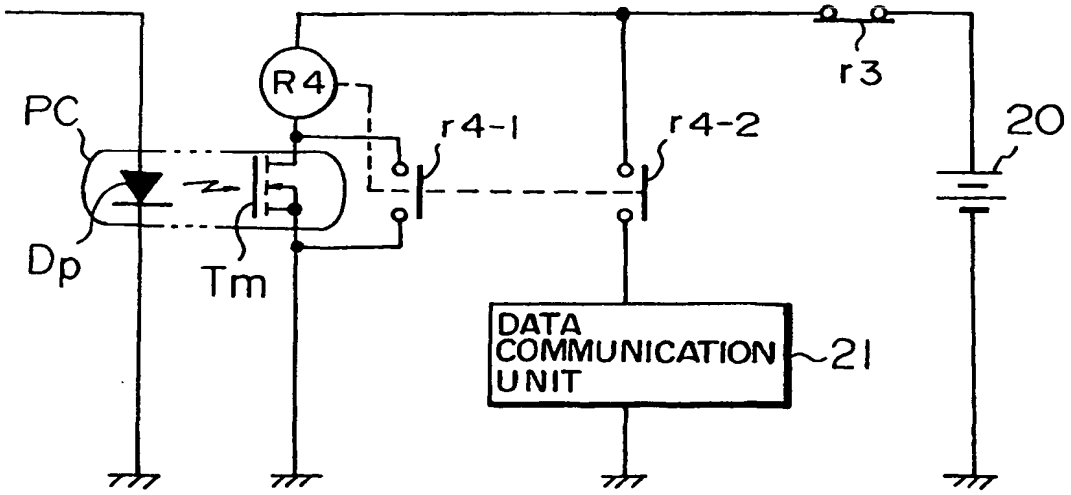


FIG. IIA

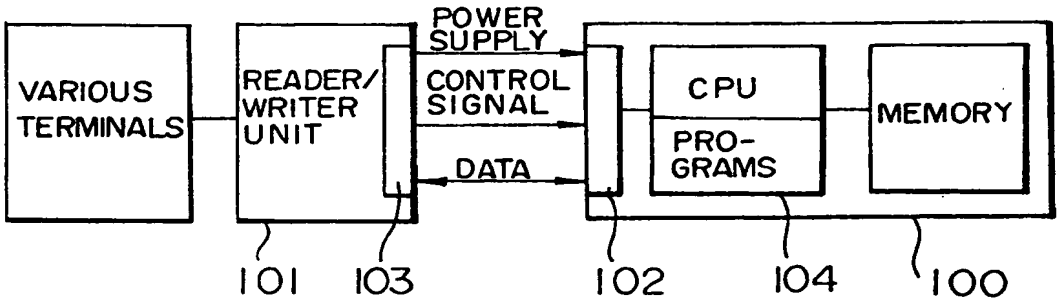
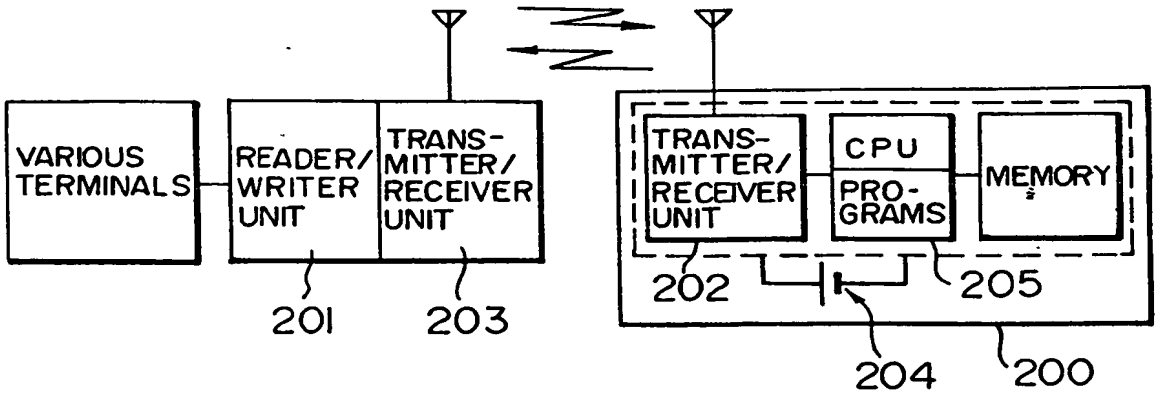


FIG. IIB
PRIOR ART



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EUROPEAN SEARCH REPORT

Application Number
EP 97 10 6100

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X Y	EP 0 552 828 A (NEDERLAND PTT) 28 July 1993 * column 6, line 20 - column 9, line 58; figures 1,2 *	1,5,7 6,8-11	G06K7/10
Y A	US 5 488 662 A (FOX THOMAS M ET AL) 30 January 1996 * column 2, line 19 - column 4, line 16; figures 1-3 *	6,8-11 2,3	
A	US 4 189 516 A (DRYBURGH PETER M ET AL) 19 February 1980	4,11	
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TECHNICAL FIELDS SEARCHED (Int.Cl.6)

G06K

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	25 July 1997	Degraeve, A

CATEGORY OF CITED DOCUMENTS

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